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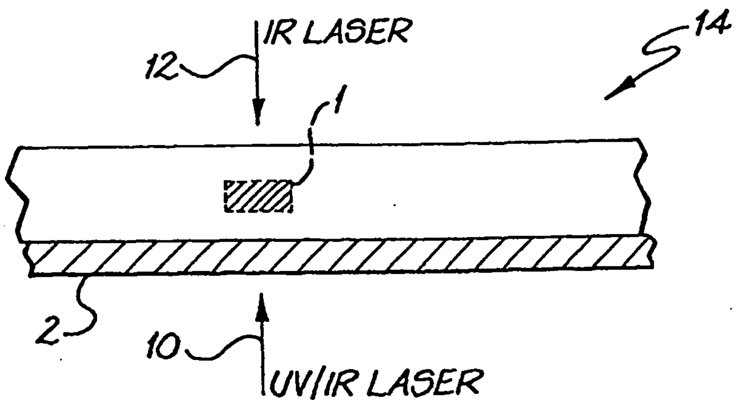

(57) Abstract

A method of tuning an optical device comprising a waveguide, the method comprising the step of applying a localised heating to the device in order to change the optical properties of the waveguide.

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TUNING OF OPTICAL DEVICES

Field of the Invention

The present invention relates to the thermal processing of waveguides so as to alter their properties.

Background of the Invention

The construction of planar optical waveguide devices is well known. These normally are constructed by depositing layers on top of a silicon substrate with portions of the deposited (and etched) layers being made photosensitive and subsequently being subjected to light of a wavelength selected to manipulate their optical properties. In this manner, often extremely complex optical waveguide devices can be built up on a silicone substrate.

It is desirable to provide for a system of post processing of the optical waveguide so as to tune the properties of any complex device of which the waveguide forms part.

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided a method of tuning an optical device incorporating a waveguide, the method comprising the step of applying a localised heating to the device in order to change the optical properties of the waveguide.

The localised heating can be applied by means of a laser device such as a UV or Infra Red laser device.

The device may comprise the waveguide formed on a substrate.

The method can e.g. be utilised in the tuning of one arm of an interferometric device.

The localised heating can be used to cause thermal relaxation, thermal diffusion or induce structural changes in the device.

In one embodiment, the method can be used to write a grating structure into the waveguide.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within

the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 illustrates schematically the process of thermal process of waveguides;

Fig. 2 illustrates an example application in a MZI type device; and

Fig. 3 illustrates an alternative form of processing of a waveguide type device.

Fig. 4 illustrates the relation between β_{stress} and β_{form} in a method embodying the present invention.

Description of Preferred and Other Embodiments

In the preferred embodiment, local thermal processing of a wafer is carried out utilizing an infra-red or UV laser device. Suitable thermally sensitive waveguides, including a negative index grating within a germanosilicate planar waveguide, can be produced by utilizing a hollow cathode plasma enhanced chemical vapour deposition (HCPECVD)process such as that outlined in M V Bazylenko, M Gross, A Simonian, P L Chu, Journal of Vacuum Science and Technology, A14, (2) pp336-345, 1996 and J Canning, D Moss, M Aslund, M Bazylenko, Election Letters, 34(4) pp366-367 (1998).

Turning now to Figure 1, the localised heating is preferably in the region of the waveguide 1 so as to alter its optical properties. Preferably, the thermal processing utilised is designed to have minimal other effects on the waveguide 1.

Hence, if a UV laser is to be utilised then may be utilised on the silicon substrate 2 which is opaque to UV rays, as illustrated by arrow 10, whilst for a IR laser may be utilised from above the waveguide 1 as illustrated by arrow 12.

The localised heating can be utilised to cause localised changes in the device 14. The changes can include thermal relaxation of internal stresses, thermal diffusion of material or thermal damage of material layers.

For example, Fig. 2 illustrates an add-drop multiplexer 10 constructed utilizing a Mach-Zehnder principle which can be initially constructed on a wafer and subsequently tuned by means of thermal rather than UV tuning of the arms at the points eg. 11, 12.

Where it is desired to utilise local radiation which may cause undesirable effects in the waveguide 100, as illustrated in Fig. 3, an opaque layer eg. 15 can be formed over the waveguide 100 so as to minimise photosensitive alternations in the area of waveguide 100.

The utilisation of local heating can have a number of uses. Firstly, as noted previously, there is its utilisation to change waveguide properties. Such utilisation would be ideal for example in Mach-Zehnder type devices. Other devices could include multimode devices wherein each arm can be thermally processed so as to adjust properties.

An alternative use for localised thermal heating is the localised heating of the substrate/wafer to control or release stresses through annealing or damaging of the wafer. E.g. it is known to construct optical waveguide devices having internal waveguide structures utilizing plasma enhanced chemical vapour deposition processes on a silicon substrate. Unfortunately, often non-symmetrical birefringence effects will result form the formation process. The first birefringent effect denoted β_{form} will be due to the circumference characteristics of the waveguide. The second effect denoted β_{stress} will be due to several stresses associated with the thermal coefficient mismatch of the substrate and deposited layer.

In an embodiment of the present invention, localised thermal heating of the above described structure could thus provide a method to alter the overall birefringence in the waveguide by either releasing existing stresses or introducing further stresses. E.g, as illustrated in Figure 4, where the "sign" of β_{stress} 200 is opposed to that of

β_{form} 202, the resultant birefringence 204 can be nullified by introducing further stresses in the direction of β_{stress} 200.

Alternatively, the localised thermal heating can be utilised as a form of annealing so as to slowly anneal the whole of a wafer whilst simultaneously measuring the waveguide properties. In this manner, the whole of the substrate can be thermally annealed on a mount with localised heating providing for a more precise annealing than that available through the utilisation of general convection heating. In this manner, the thermal annealing can be closely monitored and altered at any particular point.

The principle of localised thermal heating can be extended to the actual direct writing of thermally created device structures utilizing a small spot size for thermally induced rather than optically induced alternation of the waveguide. Again, this can be utilised for post processing of a waveguide so as to perform tuning or, alternatively, for the construction of more complex waveguide devices.

An example application is a process of polarisation control by heating of a substrate. An ideal laser source can be diode bar array at 810nm which is absorbed by the substrate and the waveguide. A CO/CO_2 laser can be used to heat the surface and affect the internal waveguides. Further, the devices can be tuned either at the waveguide or at the substrate. Preferably, an IR source is used so as to thermally heat and not damage the substrate.

It would be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

We Claim:

1. A method of tuning an optical device incorporating a waveguide, the method comprising the step of applying a localised heating to the device in order to change the optical properties of the waveguide.

2. A method as claimed in claim 1 wherein said localised heating is applied by means of a laser device.

3. A method as claimed in claim 2 wherein said laser device comprises a UV or Infra Red laser device.

4. A method as claimed in any previous claim wherein said method is utilised in the tuning of one arm of an interferometric system.

5. A method as claimed in any previous claim wherein said method is utilised in the thermal annealing of a substrate on which said waveguide is formed.

6. A method as claimed in any previous claim wherein said localised heating causes thermal relaxation, thermal diffusion or induces damage in said substrate.

7. A method as claimed in any previous claim further comprising the step of utilising said heating to write a structure into said waveguide.

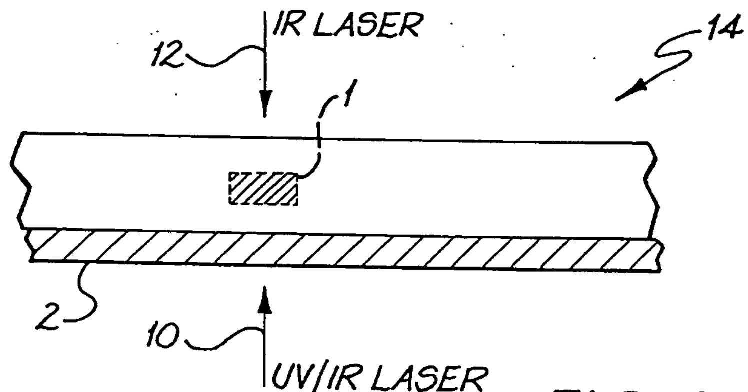

FIG. 1

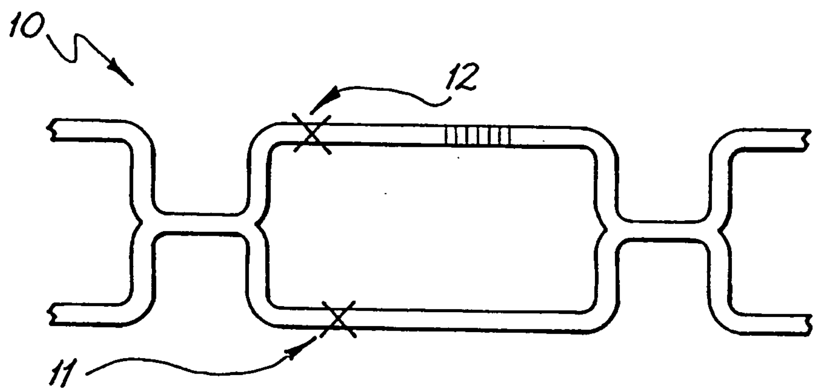

FIG. 2

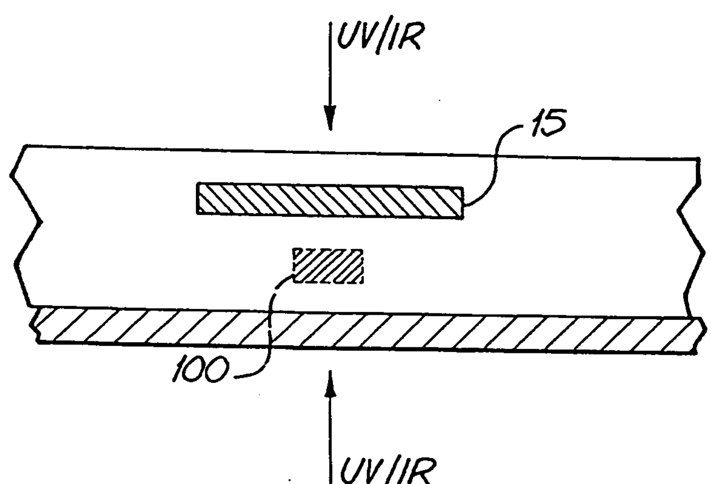

FIG. 3

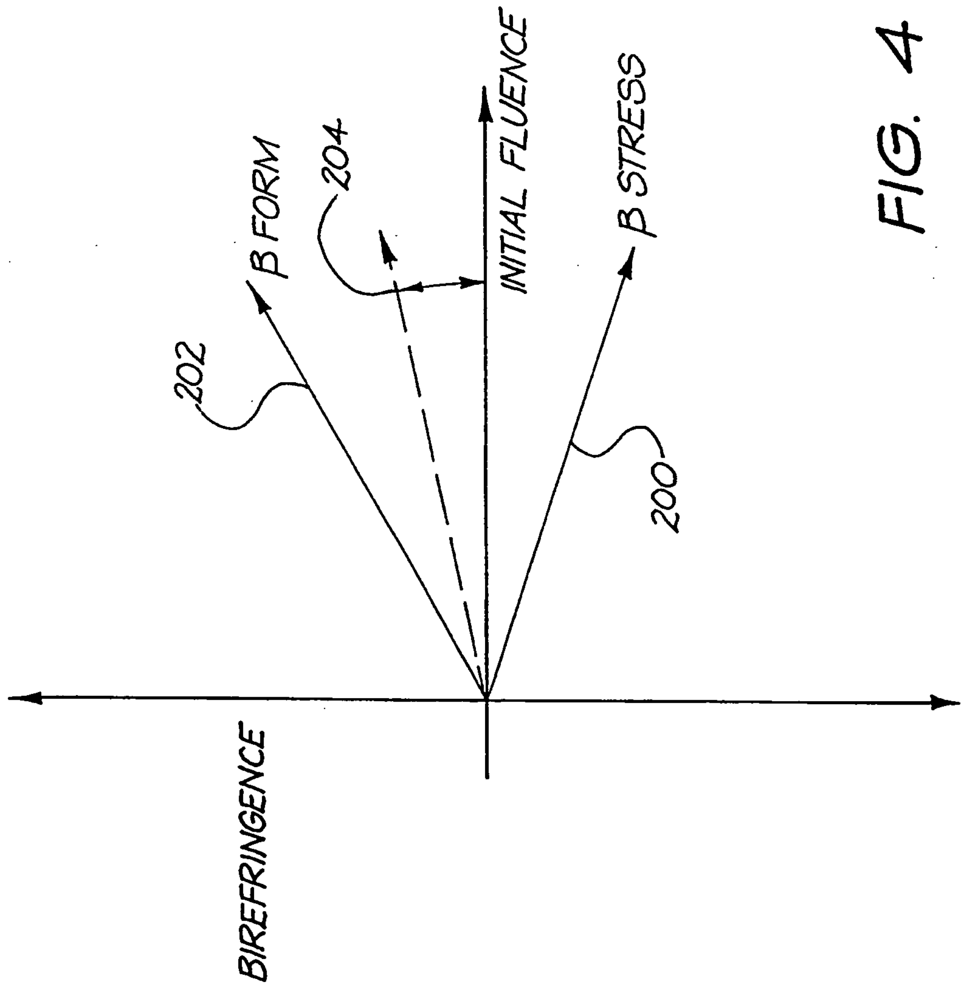

FIG. 4

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU 99/00998

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: G02B 6/12, H01L 21/324, 21/477

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC G02B 6/IC H01L 21/IC

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT, JAPIO, INSPEC : (heat+ or thermal+) and (chang+ or modif+ or alter+ or adjust+ or induc+) and (tune or tuning)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JAPIO Online Abstract JP6308546 A (NIPPON TELEGR & TELEPH CORP) 4 November 1994 See abstract	1-4, 6 4
X	Derwent Abstract Accession No 91-193987/27, Class P81, DD 286883 A (FR SCHILLER UNIV) 7 February 1991 See abstract	1, 5, 6
X Y	US 5235659 A (ATKINS *et al*) 10 August 1993 See whole document	1-3, 5-7 4

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

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Date of the actual completion of the international search 12 November 1999	Date of mailing of the international search report 19 JAN 2000
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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Derwent Abstract Accession No 97-354418/33, Class V07, JP 09145942 A (NIPPON TELEGR & TELEPH CORP) 6 June 1997 See abstract	1-3, 6 4
X	US 5805751 A (KEWITSCH *et al*) 8 September 1998 See whole document	1, 6, 7
X	US 5647040 A (MODAVIS *et al*) 8 July 1997 See whole document	1-3, 6
X	US 4737002 A (BOUCOUVALAS) 12 April 1988 See whole document	1, 6
X	US 5621843 A (NEUBERGER) 15 April 1997 See whole document	1-3, 5
X	US 5495548 A (BILODEAU *et al*) 27 February 1996 See whole document	1-3, 7
X Y	US 5349437 A (BOBB) 20 September 1994 See whole document	1, 4, 6 4

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU 99/00998

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5235659	EP	569182	JP	6118257	US	5287427
		US	5478371	US	5500031	EP	622343
		JP	6345475	EP	702252	JP	8081231
US	5805751	AU	71523/96	EP	850430	WO	9708574
		CA	2233327	EP	857314	US	5875272
		WO	9715851	AU	76645/96		
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US	4737002	EP	183449	GB	8429430	GB	2167575
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US	5495548	CA	2115906	DE	4404874	FR	2704323
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